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FIG 1

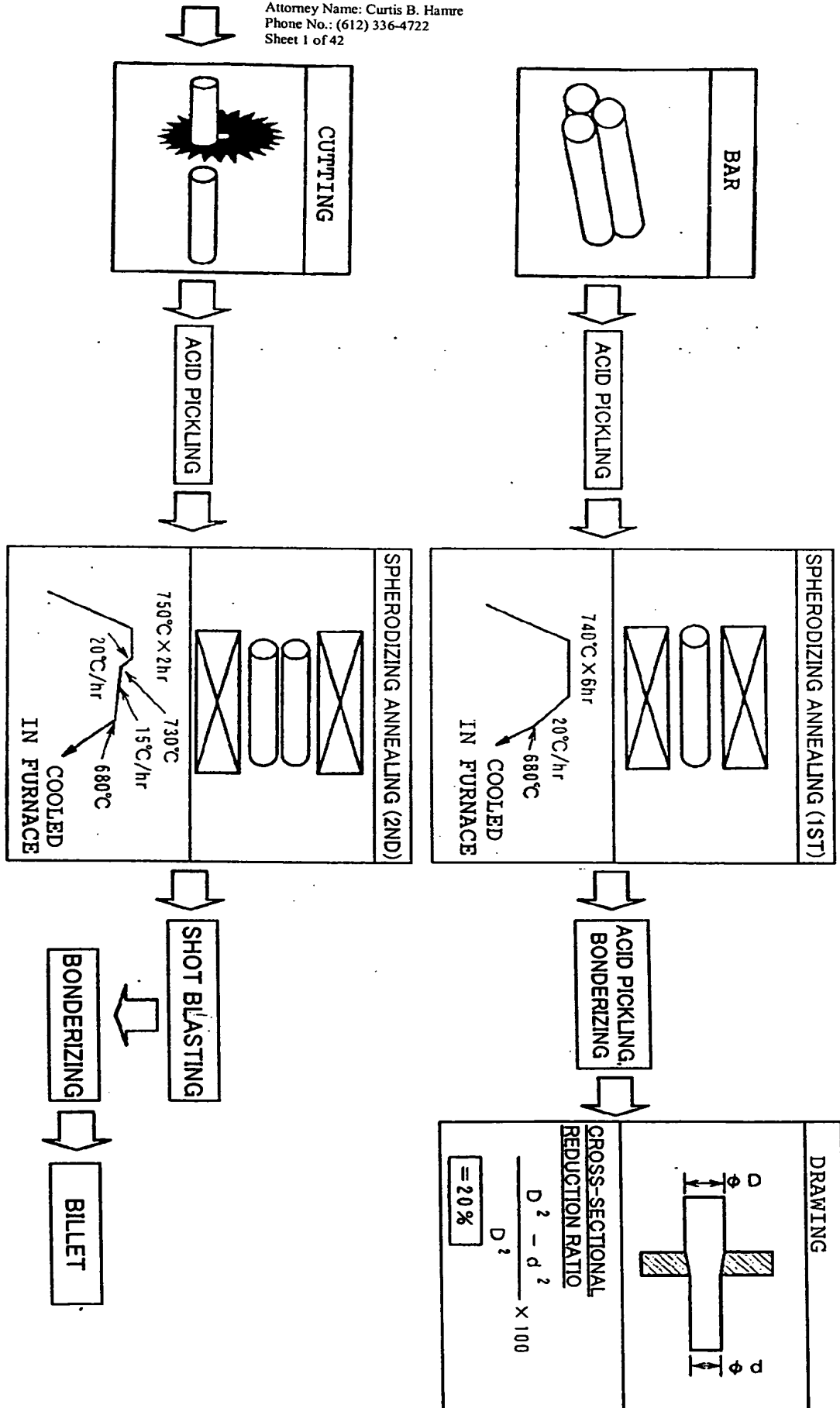


FIG. 2

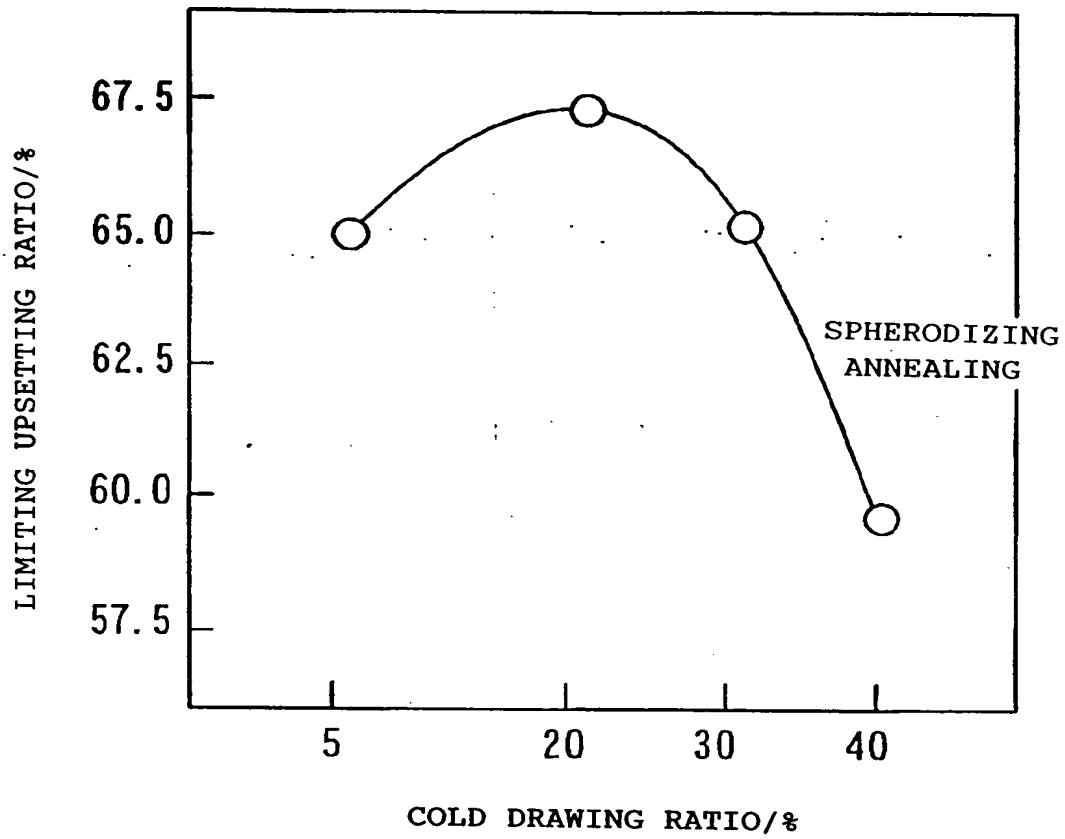
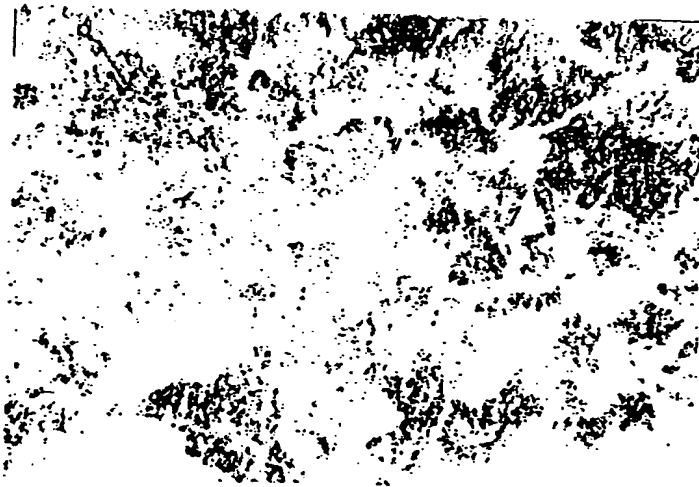


FIG. 3

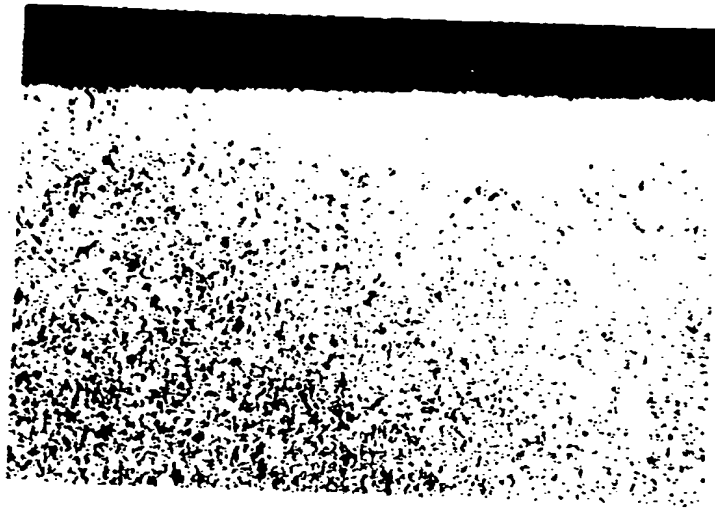


(a)

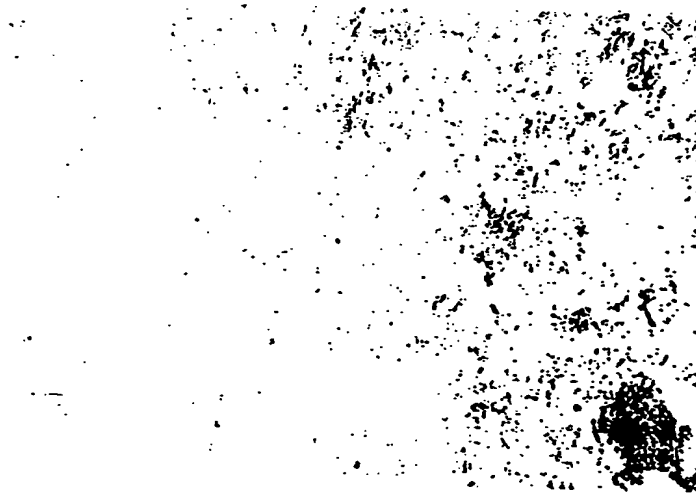


(b)

FIG. 4

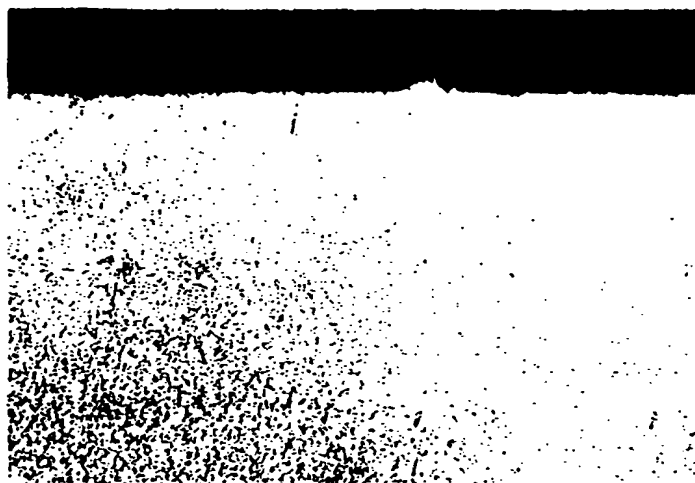


(a)



(b)

FIG. 5



(a)



(b)

FIG. 6

(A) MATERIAL 1

ASPECT RATIO = 506 %



(B) MATERIAL 2

ASPECT RATIO = 347 %



(C) MATERIAL 3

ASPECT RATIO = 300 %

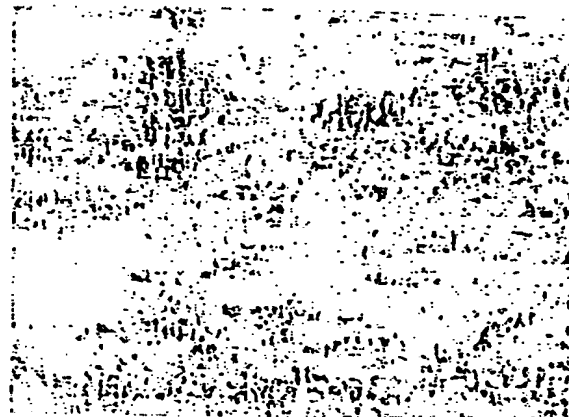


FIG. 7

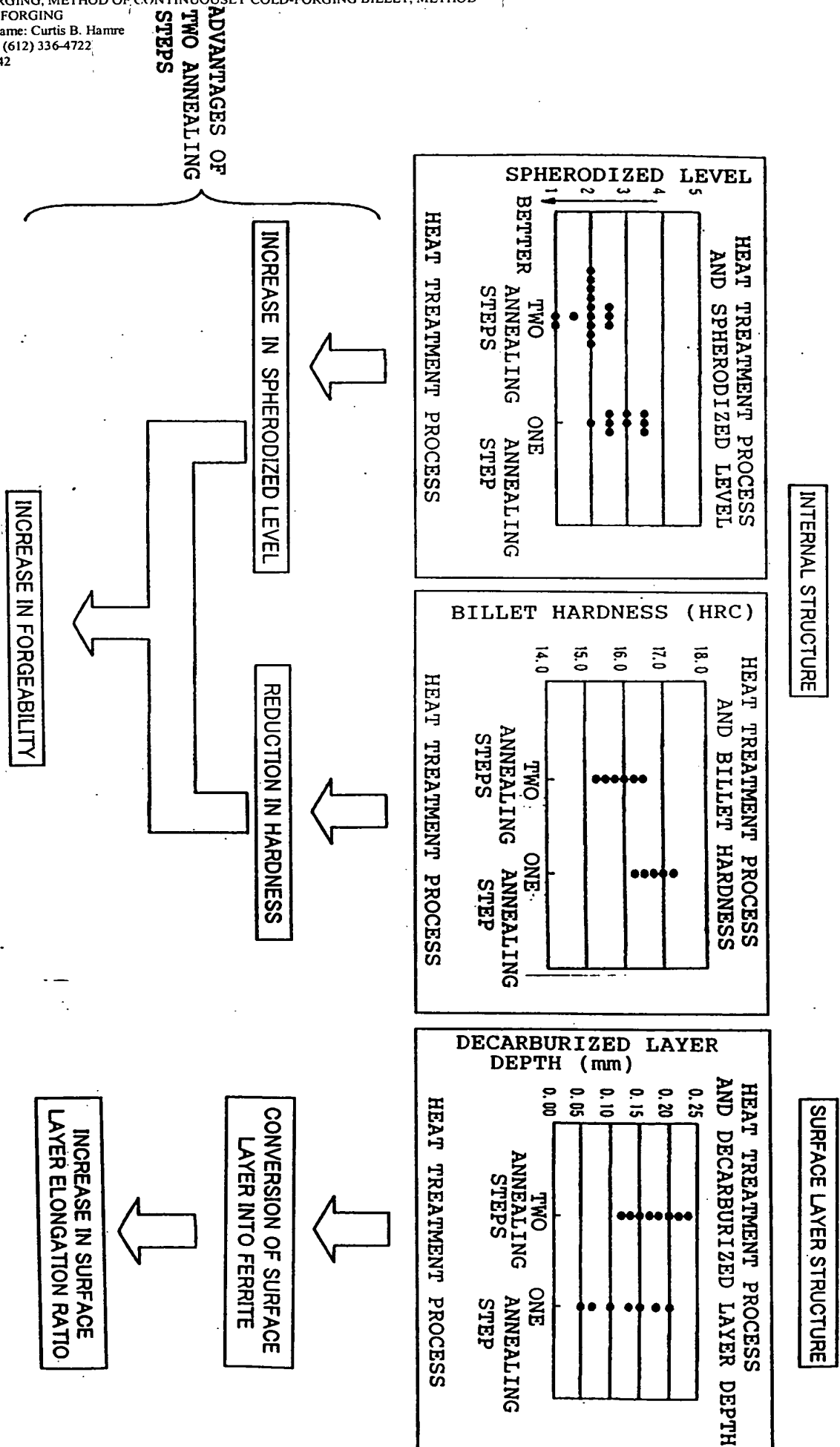


FIG. 8

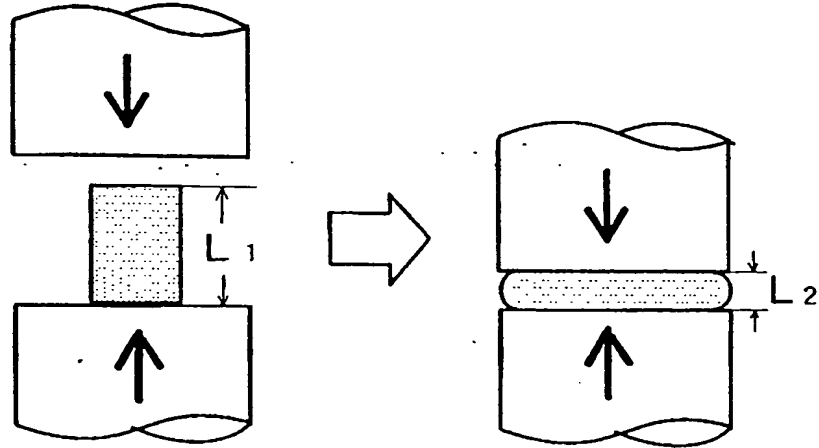


FIG. 9

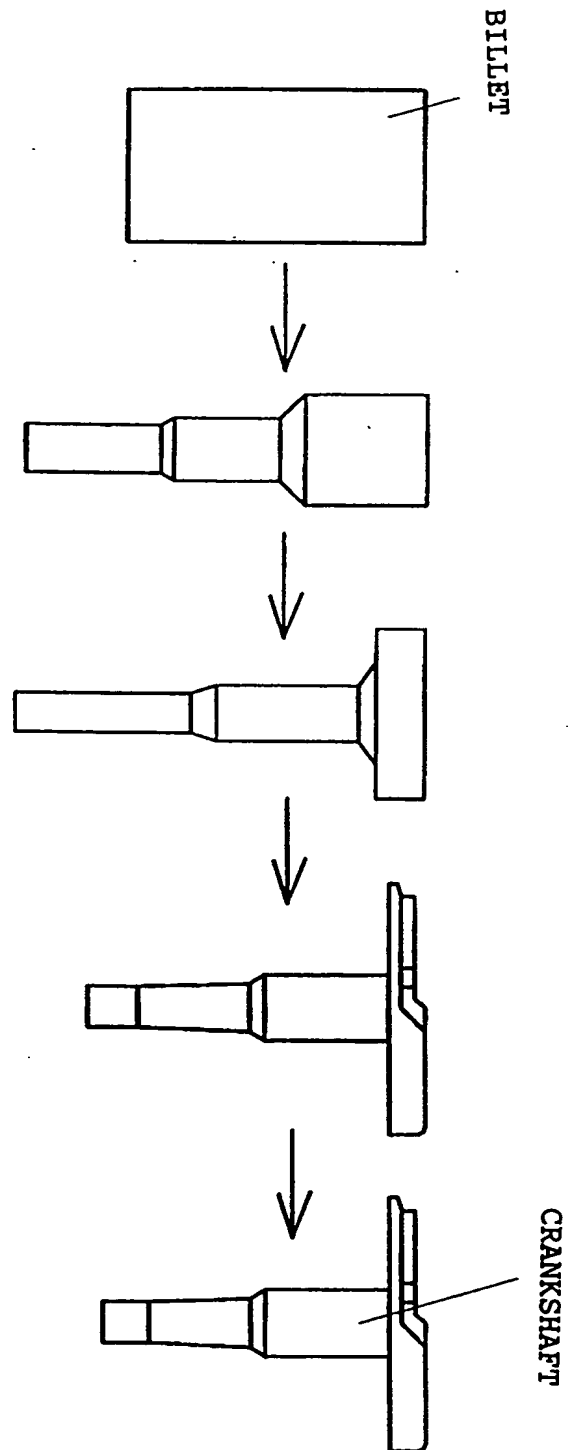


FIG. 10

Inventor: Ando, et al
Docket No.: 12052.33USD2
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 10 of 42

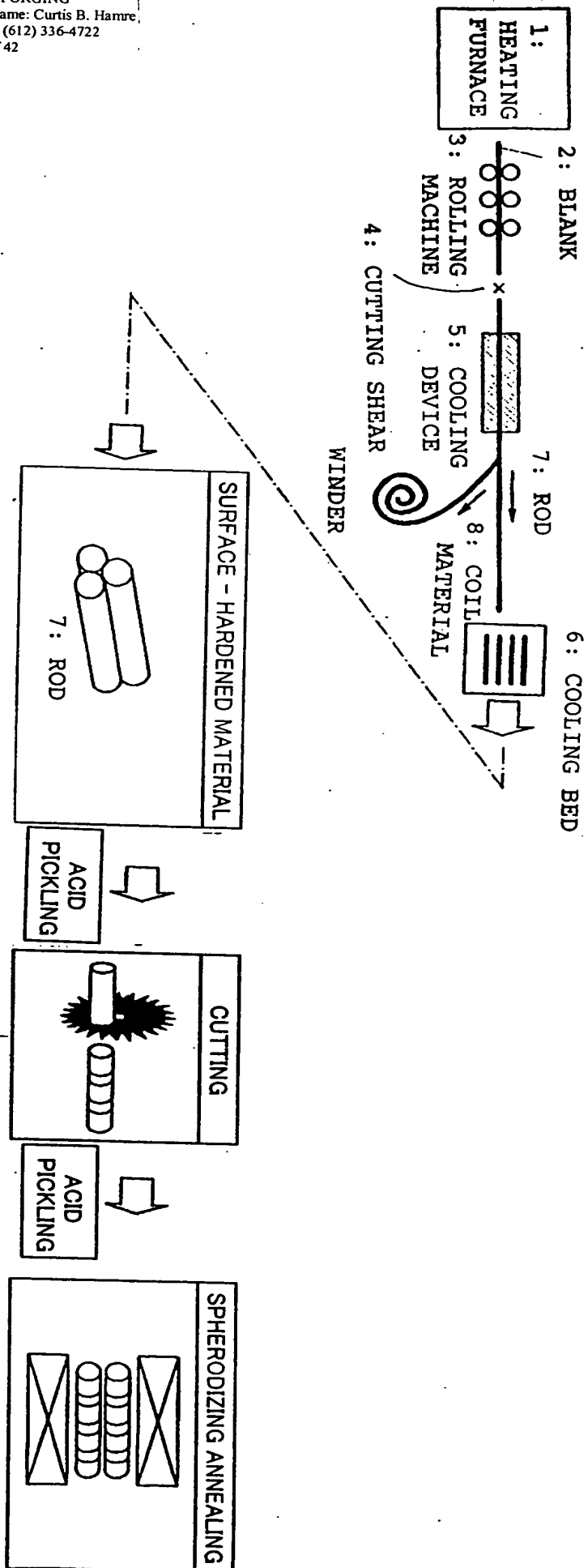


FIG. 11

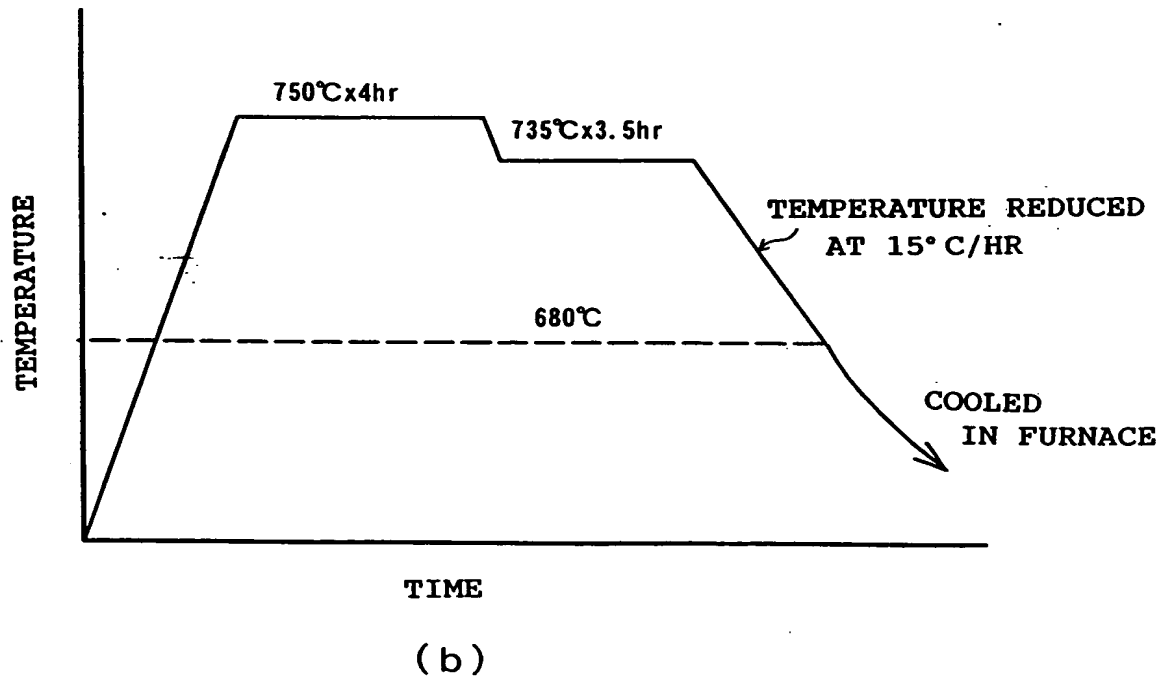
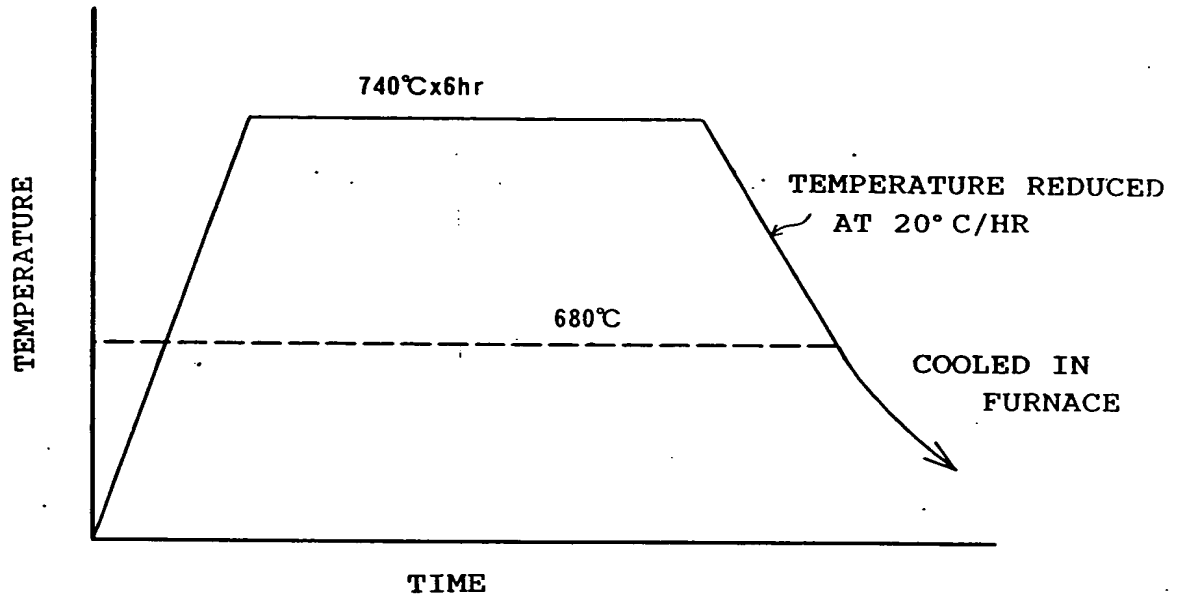
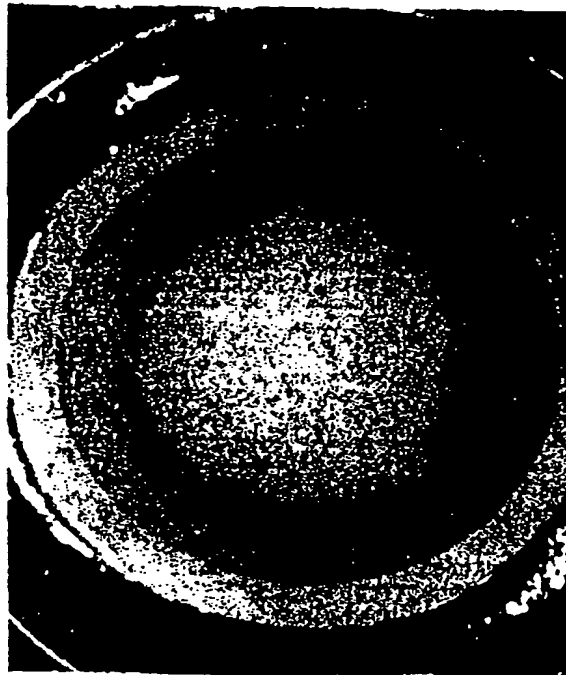


FIG. 12



MARTENSITIC MATERIAL
(a) PRIOR TO SPHERODIZING ANNEALING
× 2. 1

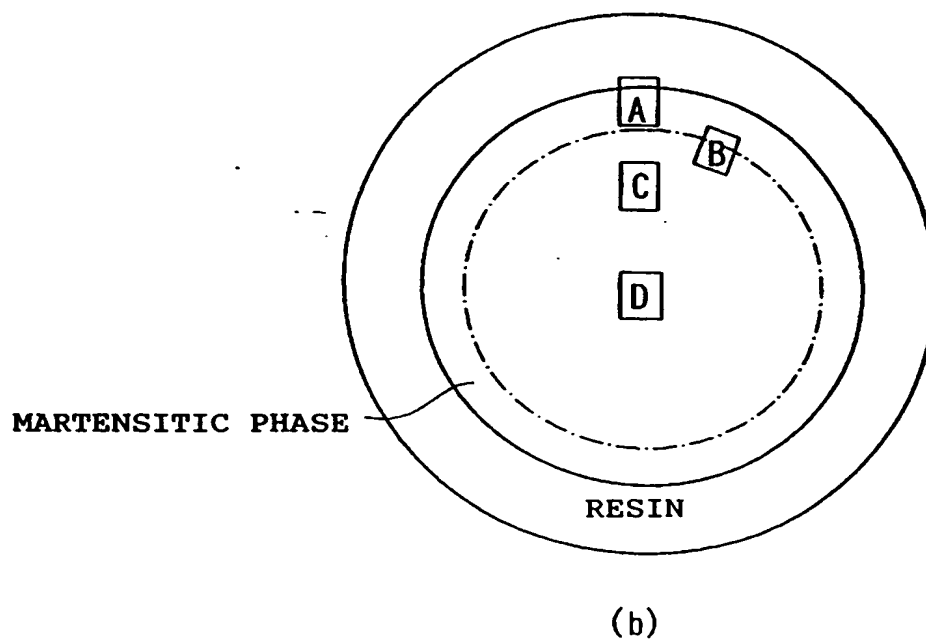
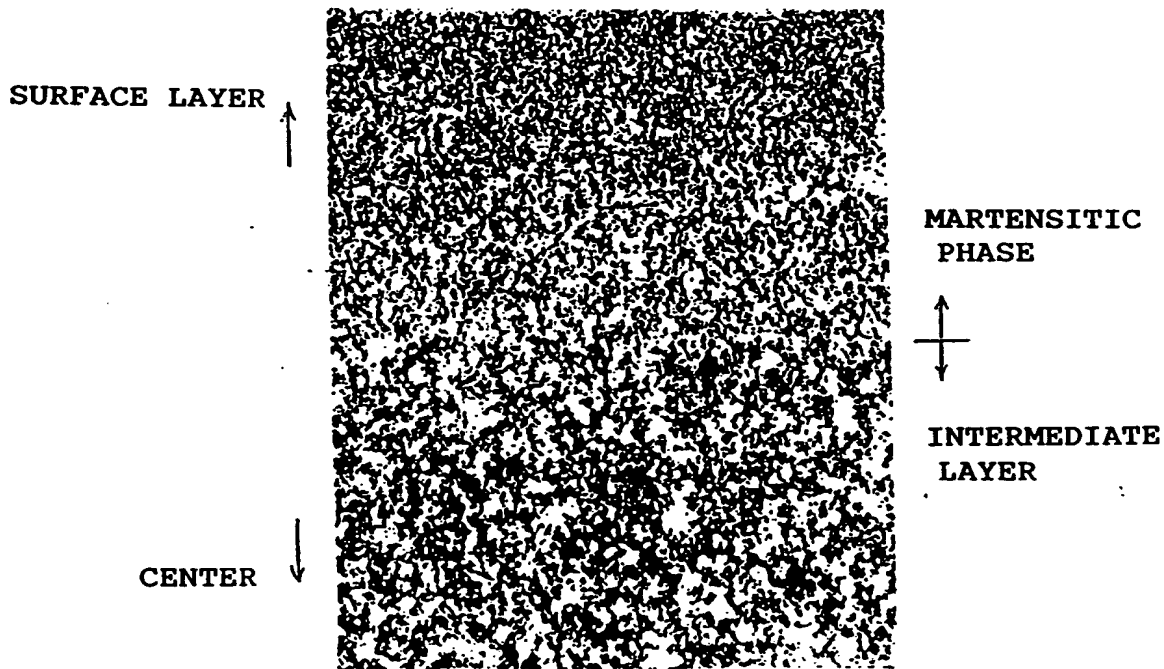


FIG. 13



PRIOR TO SPHERODIZING ANNEALING
SURFACE LAYER $\times 100$

FIG. 14



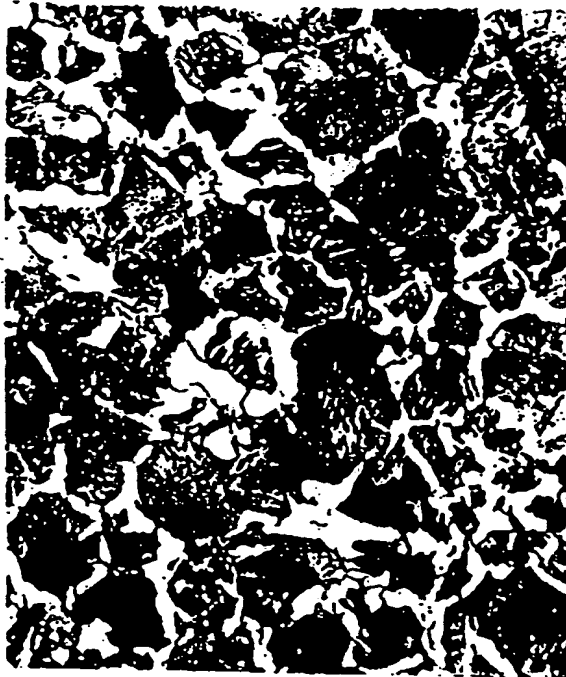
PRIOR TO SPHERODIZING ANNEALING
SURFACE LAYER AND INTERMEDIATE LAYER $\times 200$

FIG. 15



PRIOR TO SPHERODIZING ANNEALING
1/2 R PART \times 400

FIG. 16



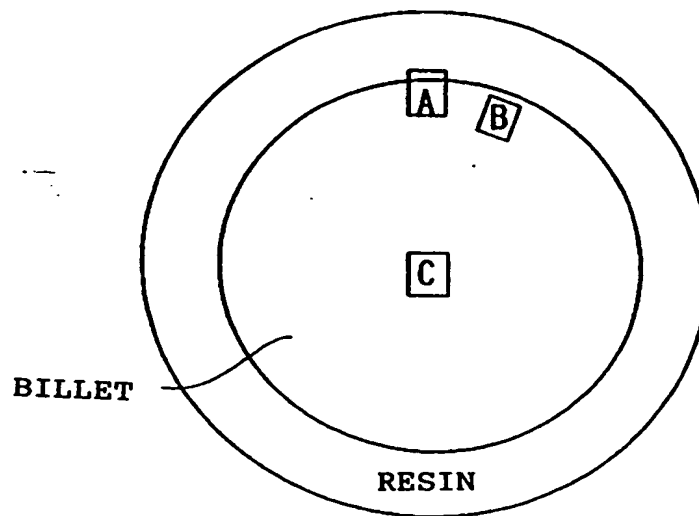
PRIOR TO SPHERODIZING ANNEALING
CENTRAL PART \times 400

FIG. 17



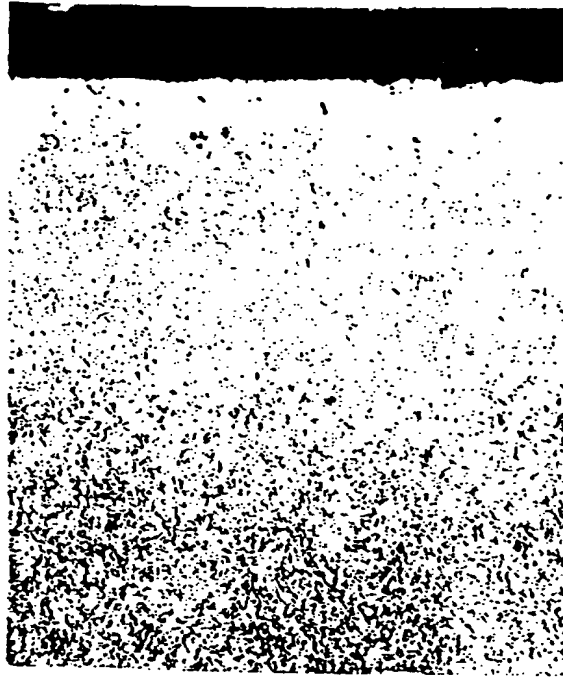
MARTENSITIC MATERIAL
AFTER SPHERODIZING ANNEALING PATTERN 1
x 2. 1

(a)



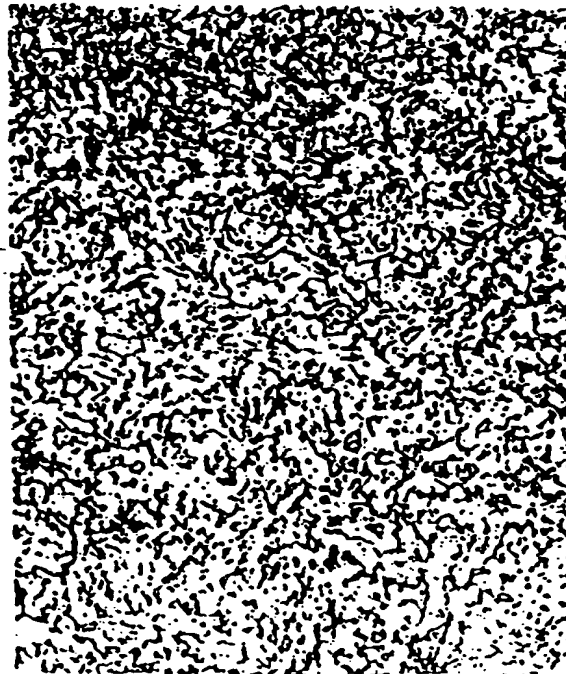
(b)

FIG. 18



AFTER SPHERODIZING ANNEALING PATTERN 1
SURFACE LAYER $\times 100$

FIG. 19



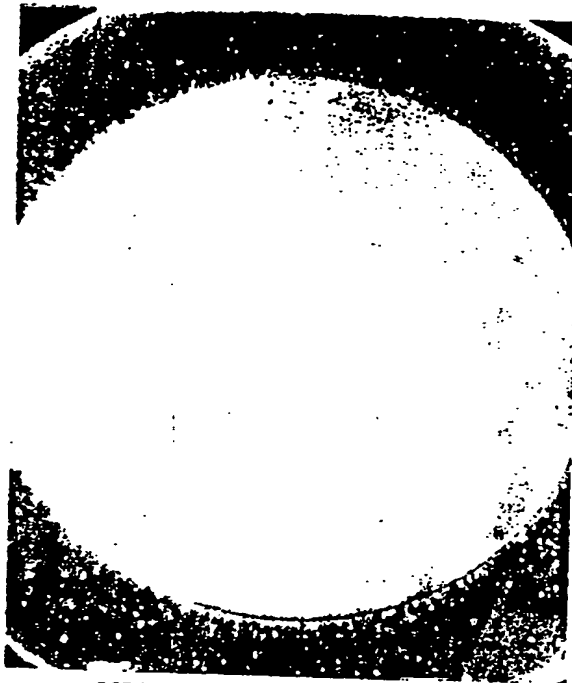
AFTER SPHERODIZING ANNEALING PATTERN 1
SURFACE LAYER $\times 400$

FIG. 20



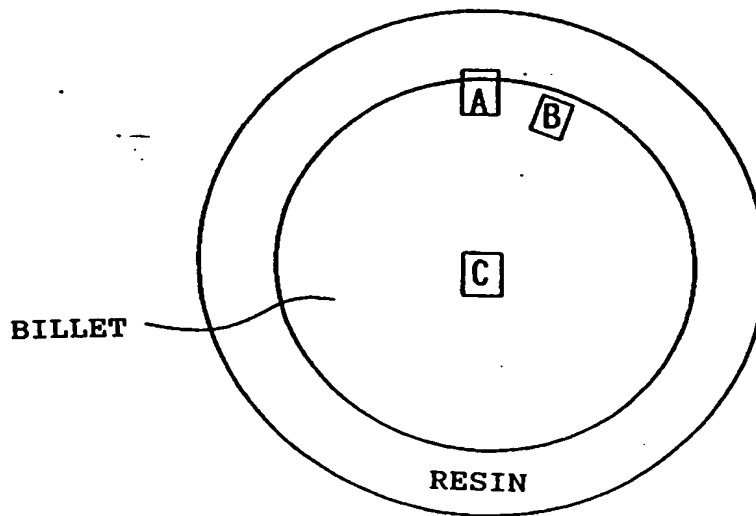
AFTER SPHERODIZING ANNEALING PATTERN 1
1/2 R PART \times 400

FIG. 21



MARTENSITIC MATERIAL
AFTER SPHERODIZING ANNEALING PATTERN 2
x 2. 1

(a)



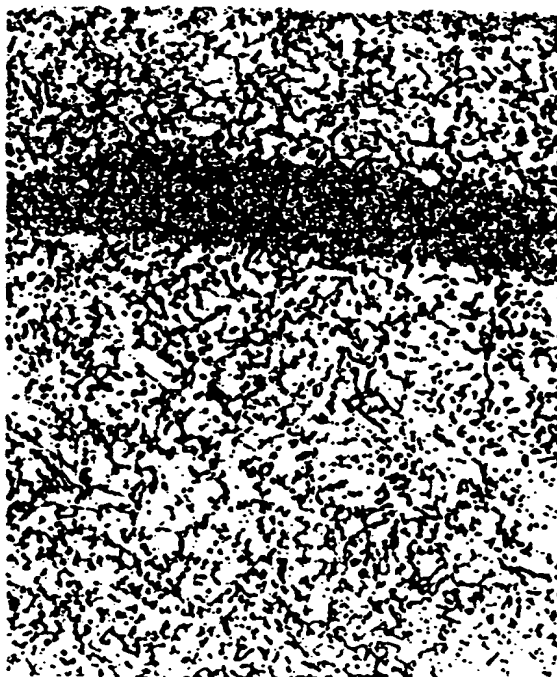
(b)

FIG. 22



AFTER SPHERODIZING ANNEALING PATTERN 2
SURFACE LAYER $\times 100$

FIG. 23



AFTER SPHERODIZING ANNEALING PATTERN 2
SURFACE LAYER $\times 400$

FIG. 24



AFTER SPHERODIZING ANNEALING PATTERN 2
1/2 R PART \times 400

FIG. 25

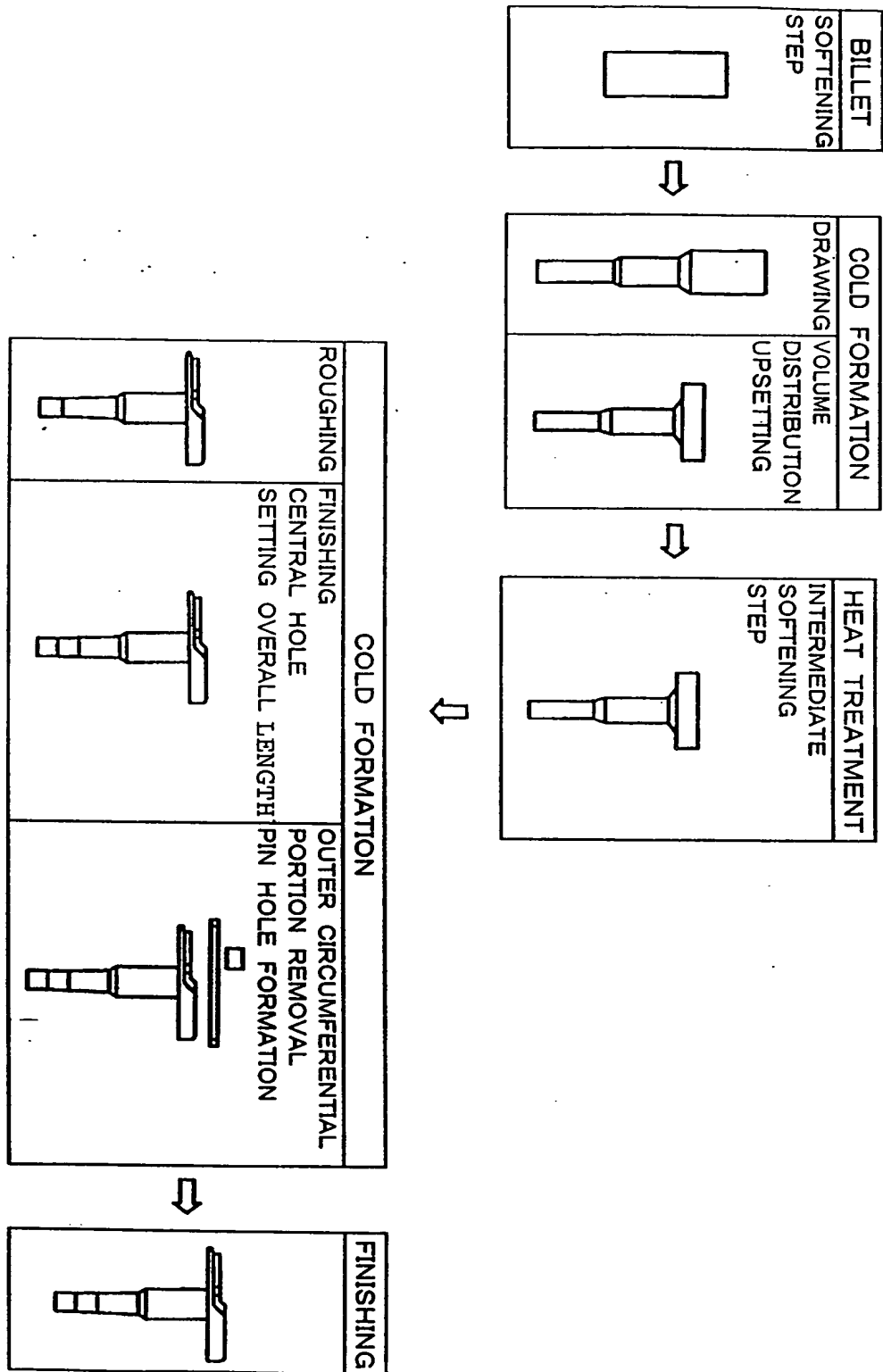


FIG. 26

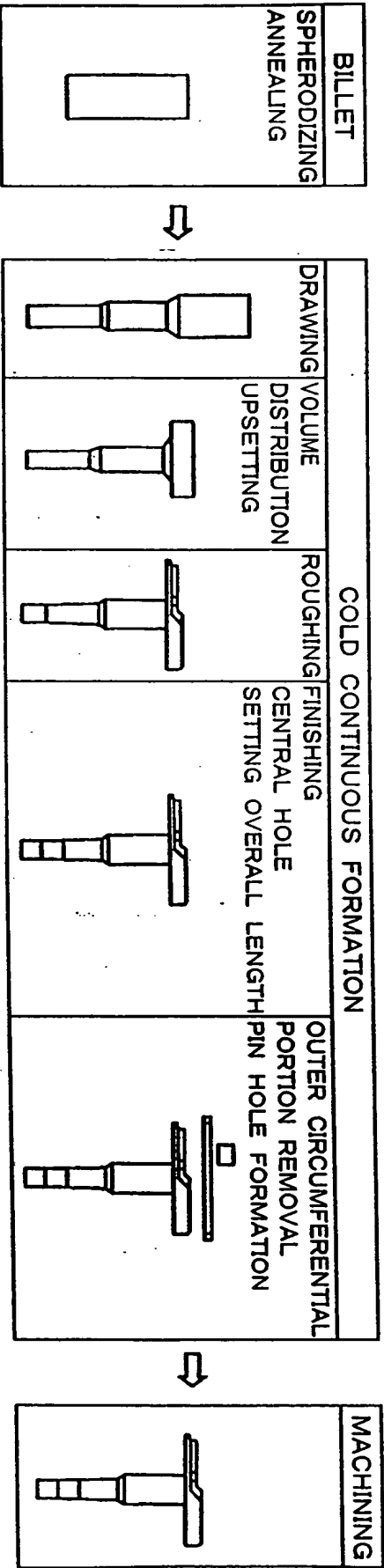


FIG. 27

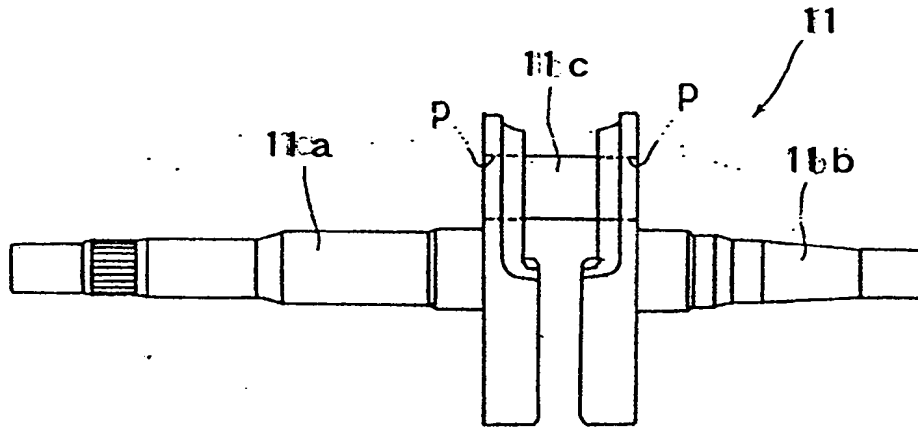


FIG. 28

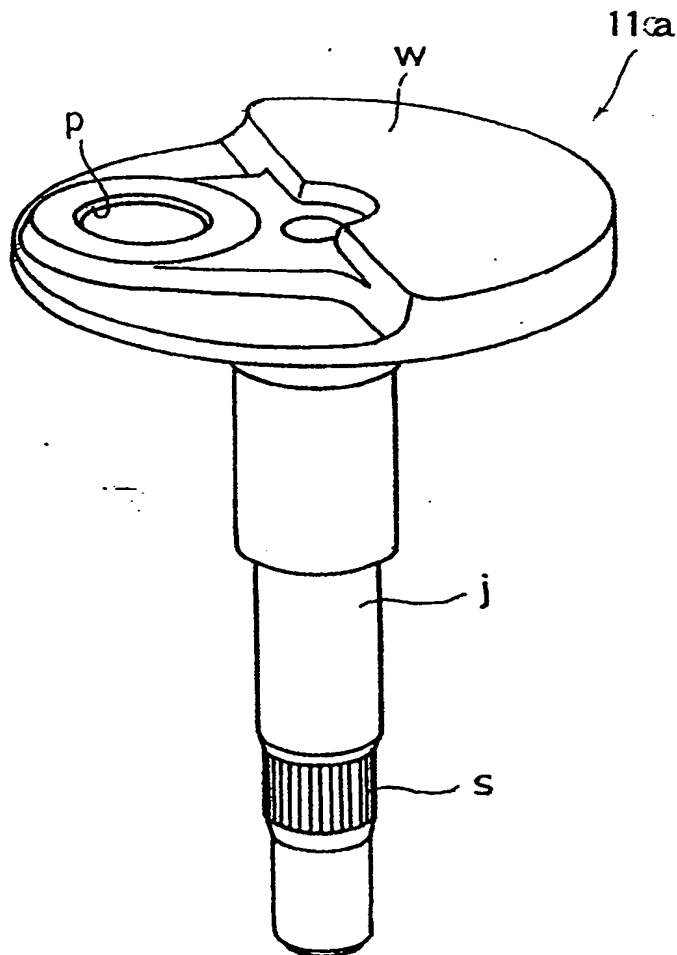


FIG. 29

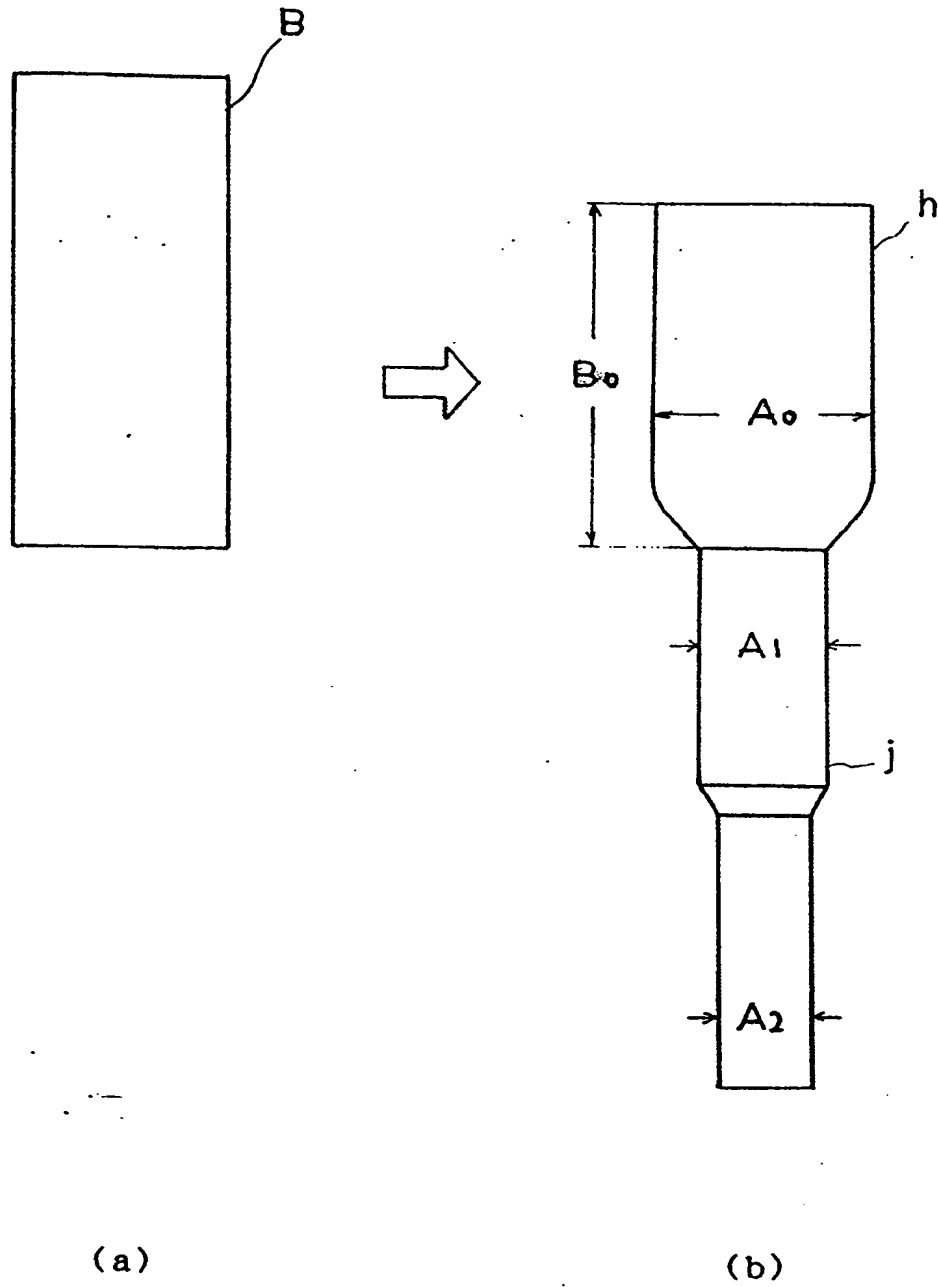


FIG. 30

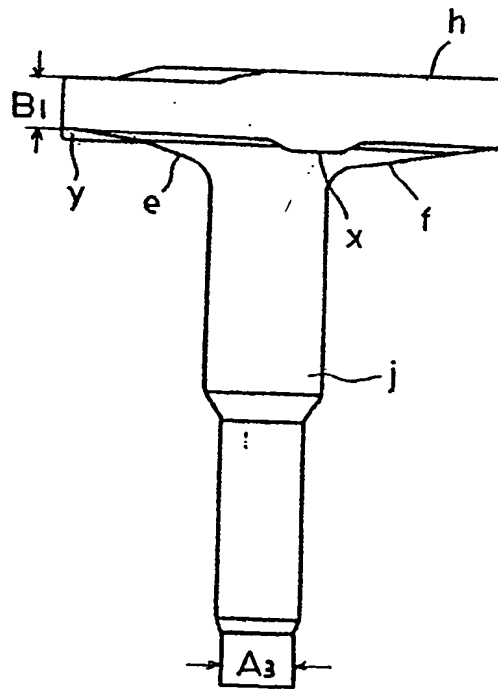
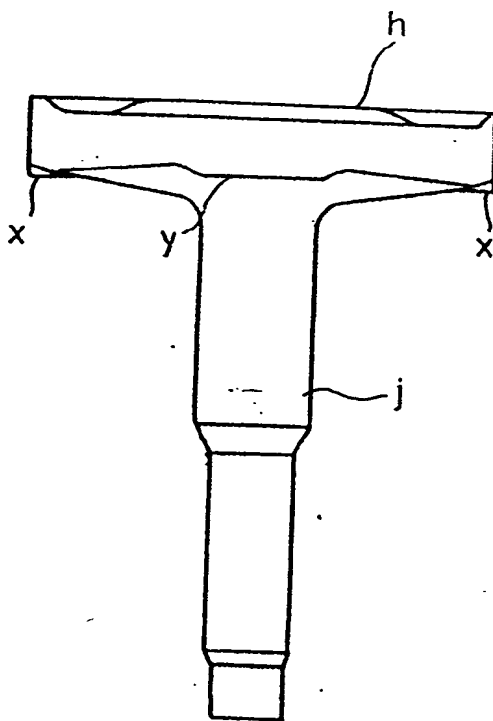
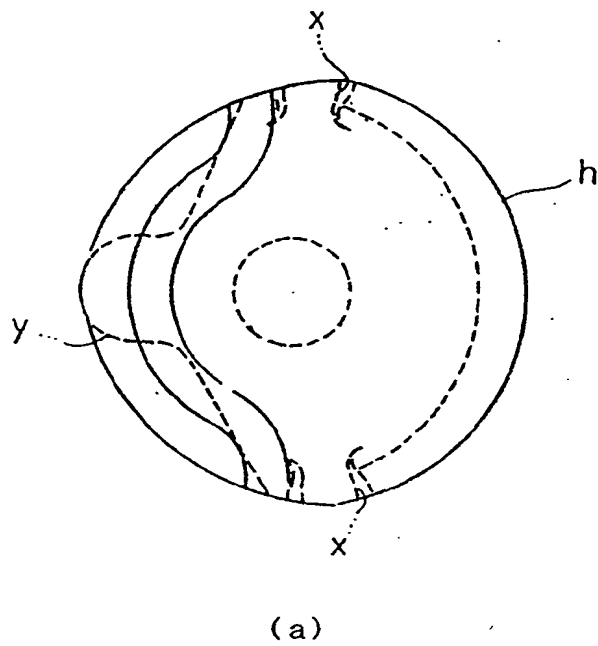


FIG. 31

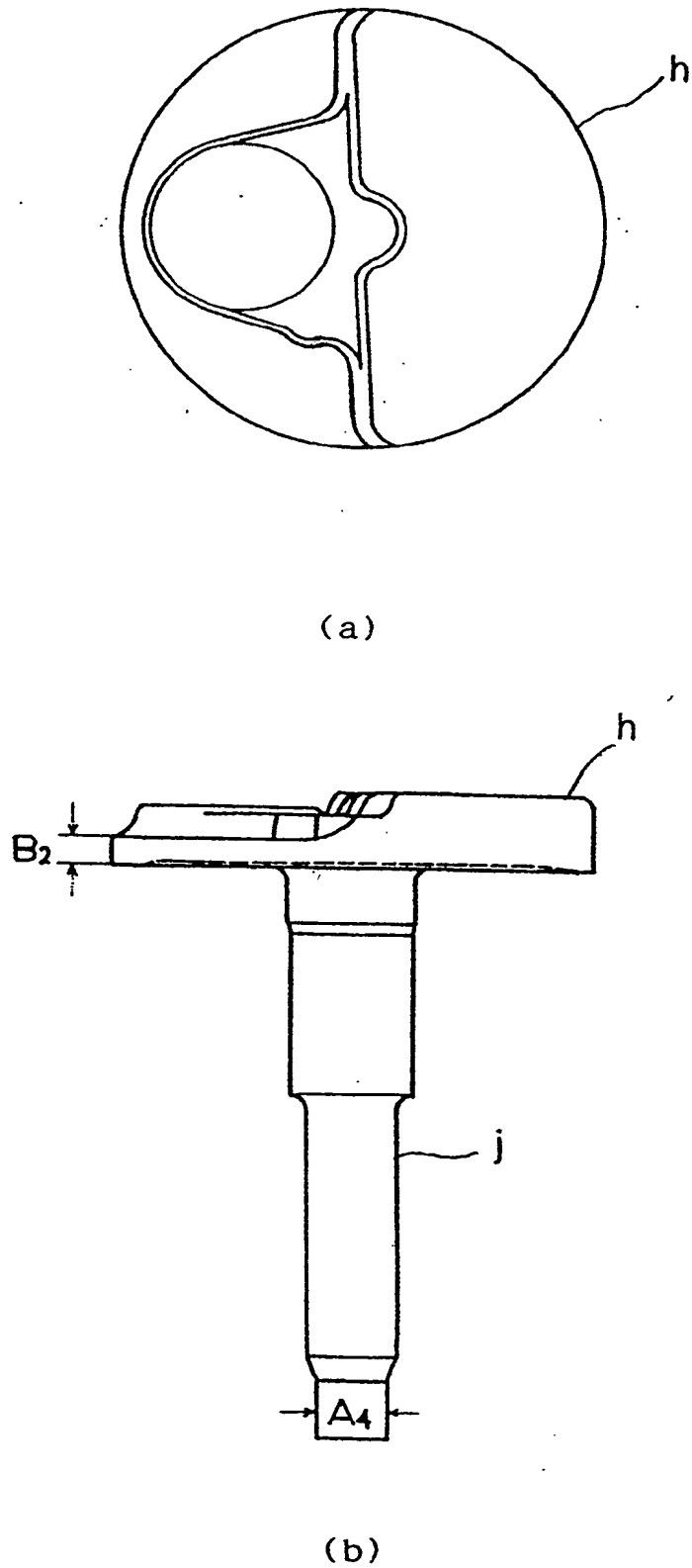
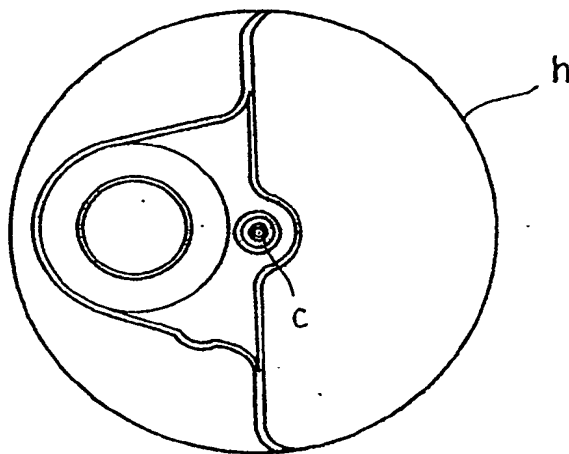
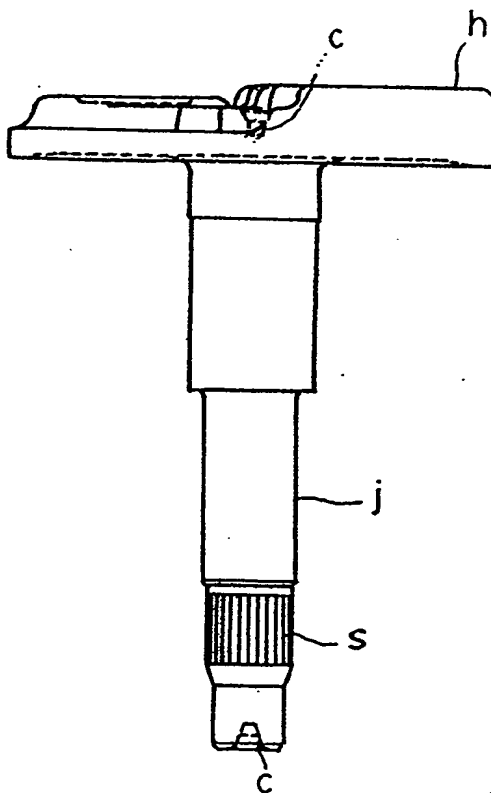


FIG. 32

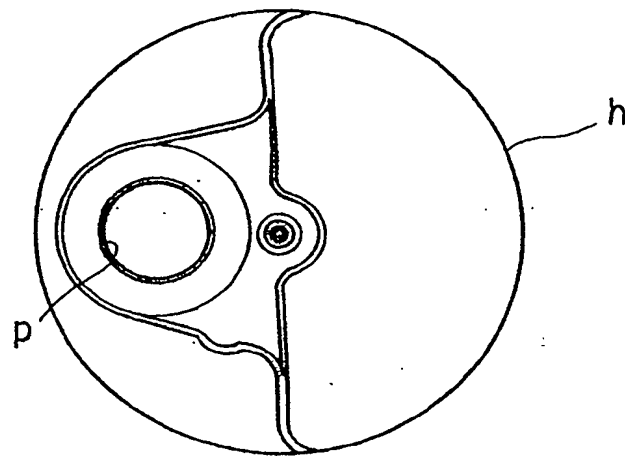


(a)

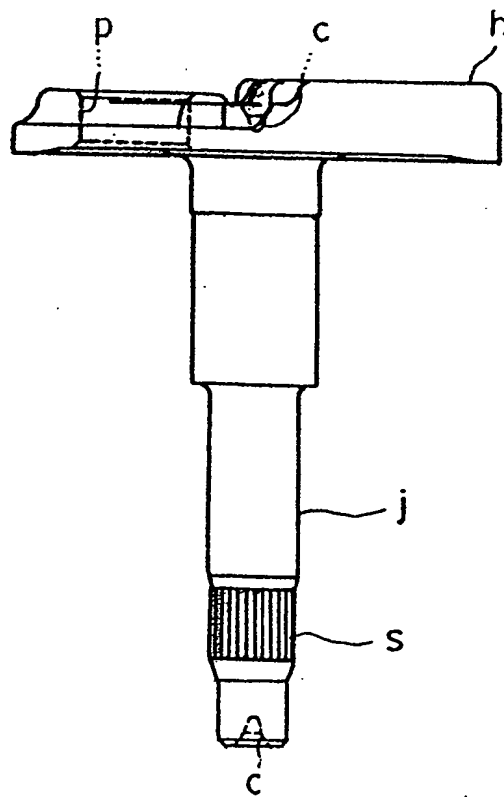


(b)

FIG. 33



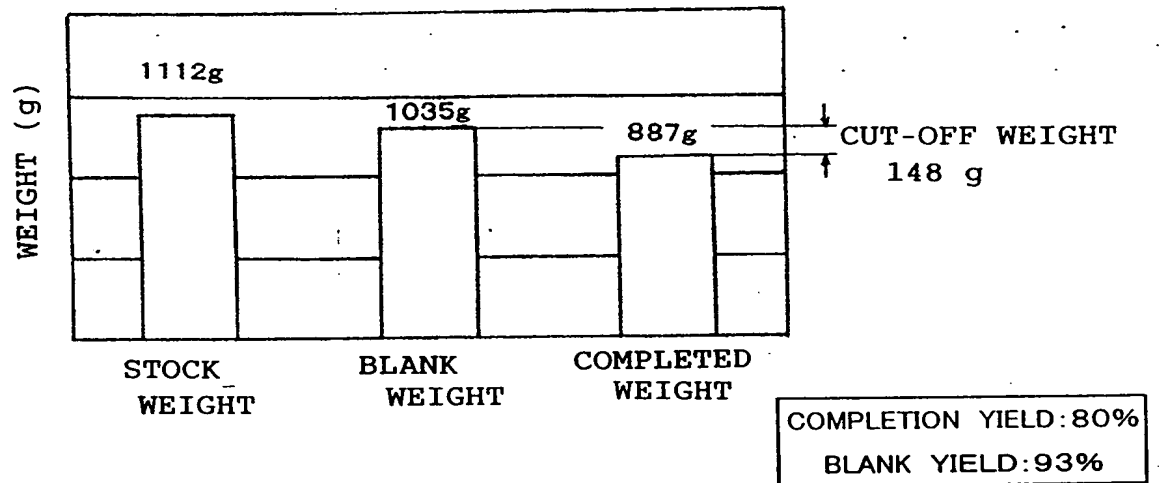
(a)



(b)

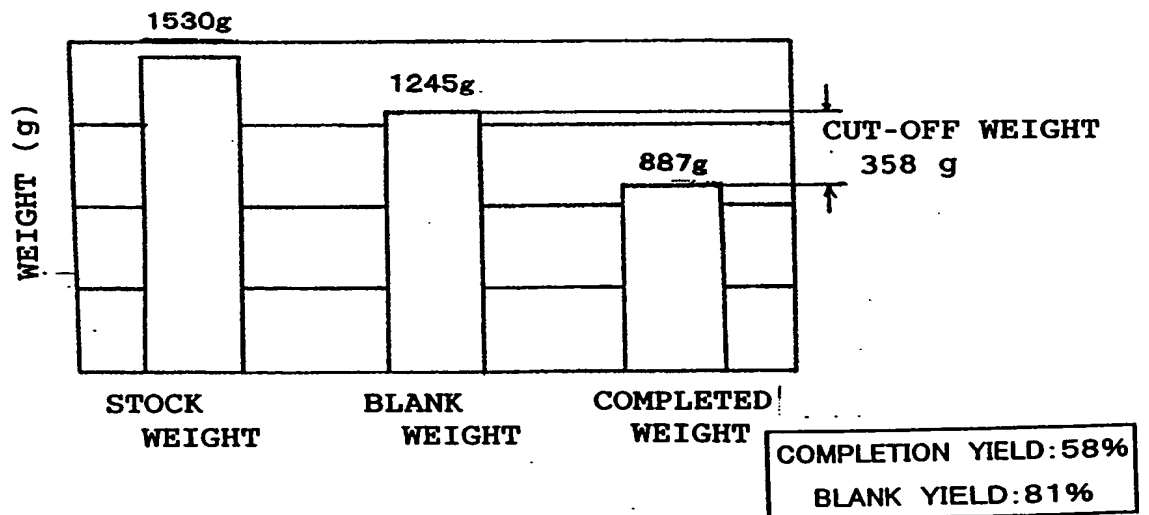
FIG. 34

(INVENTIVE COLD-FORGING METHOD)



(a)

(CONVENTIONAL COLD-FORGING METHOD)



(b)

FIG. 35

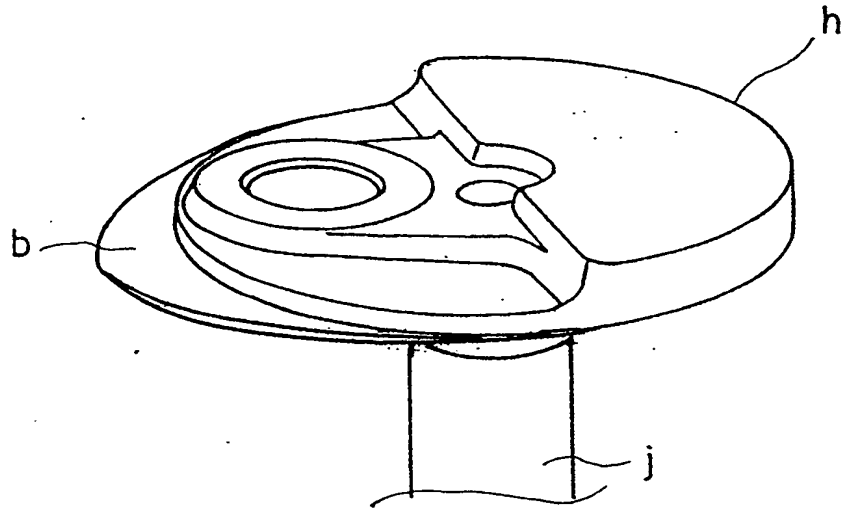
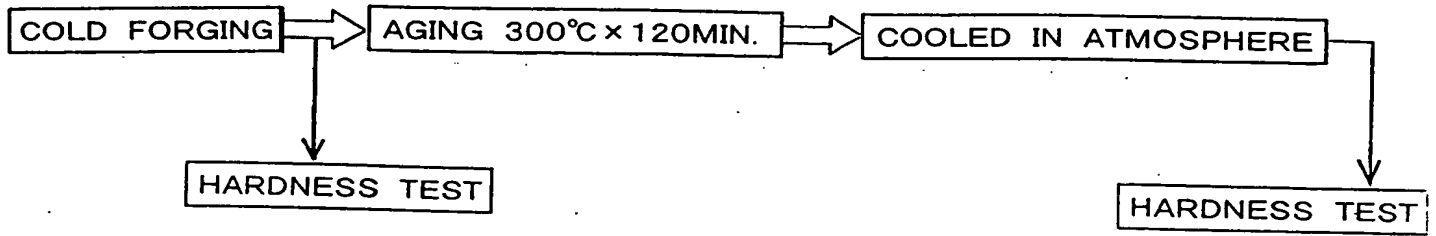
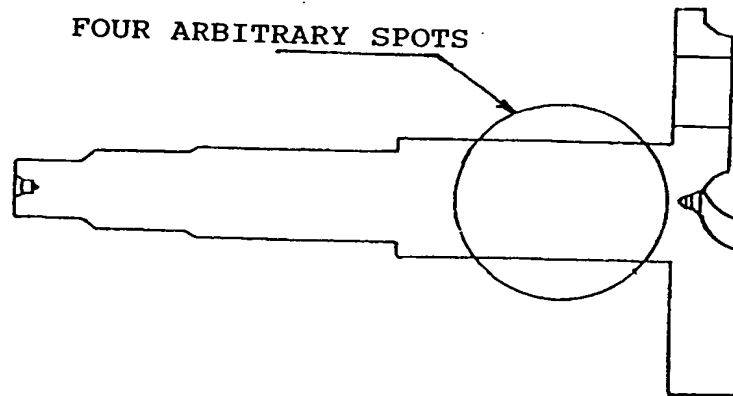


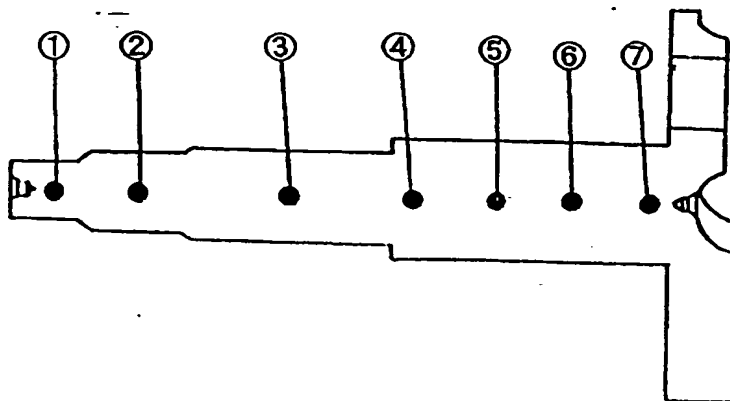
FIG. 36



(a)



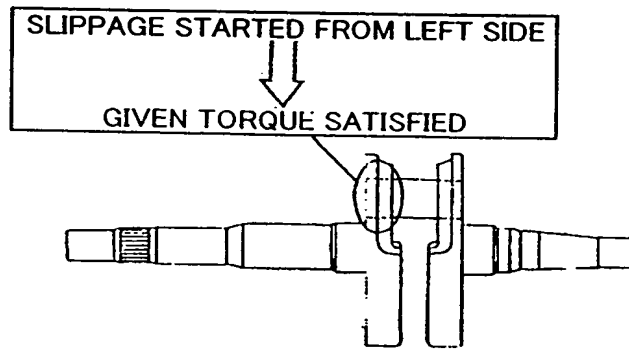
(b)



(c)

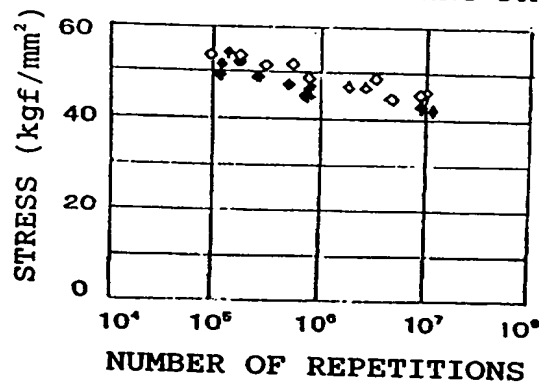
FIG. 37

SLIP TORQUE



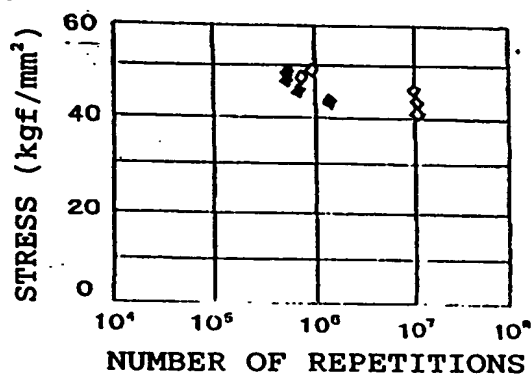
(a)

S - N CURVE (ROTATIONAL BENDING FATIGUE TEST)



(b)

S - N CURVE (SOLID BENDING FATIGUE TEST)



(c)

FIG. 38

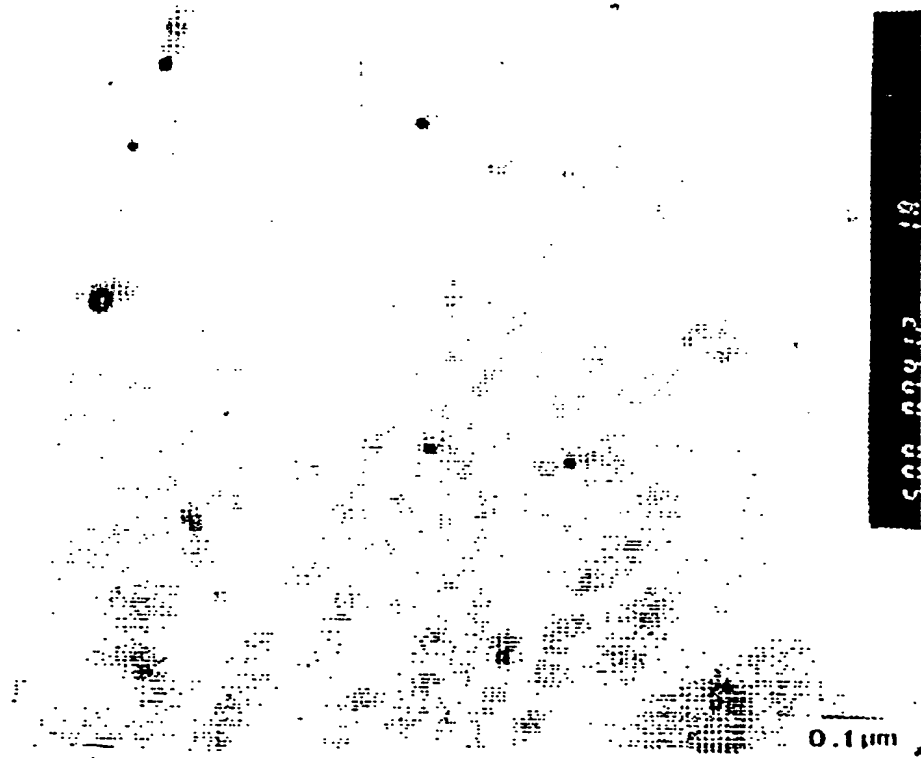


FIG. 39

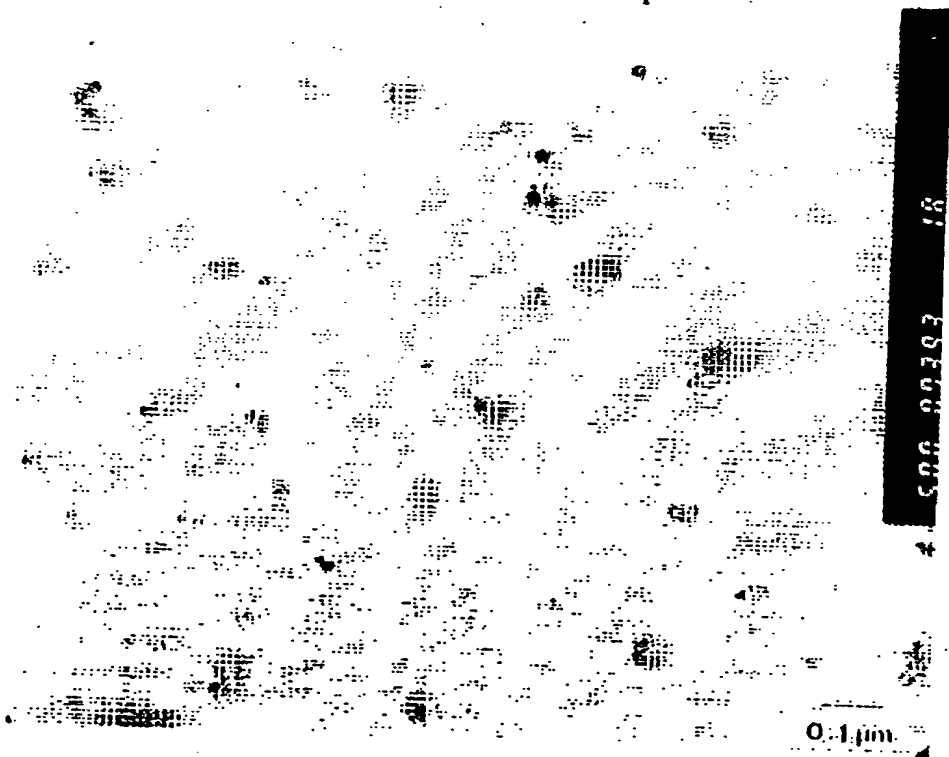


FIG. 40

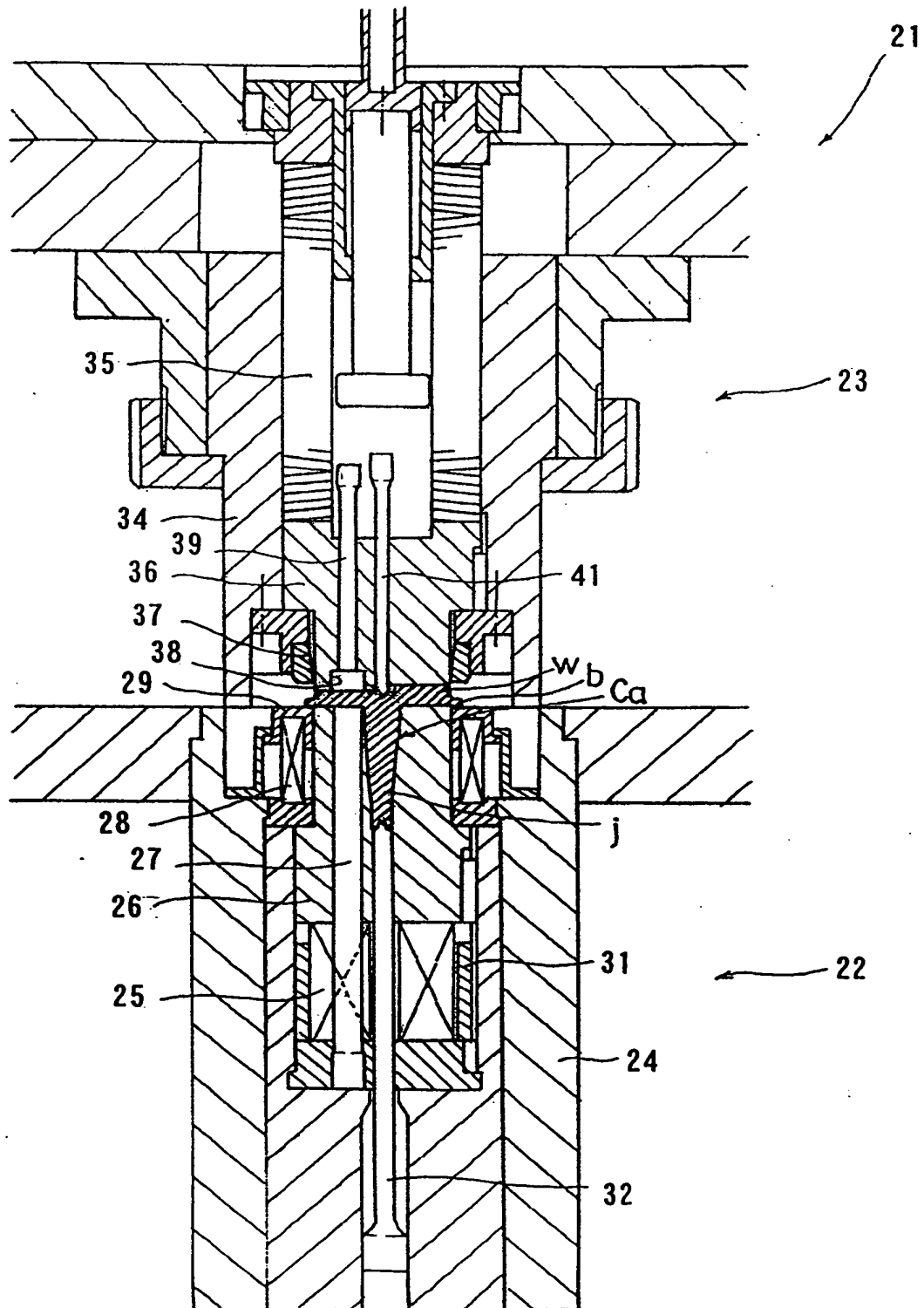


FIG. 41

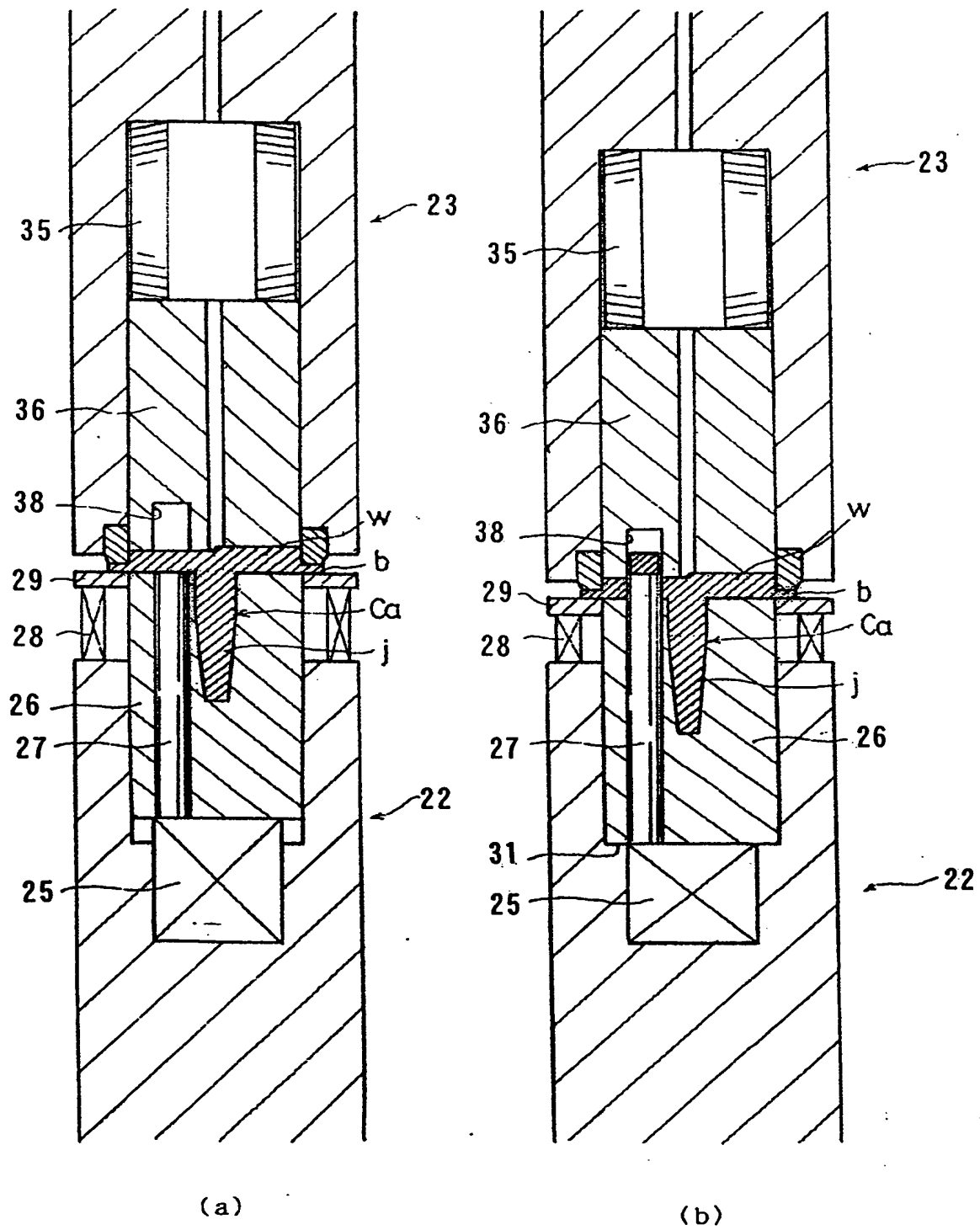




FIG. 43

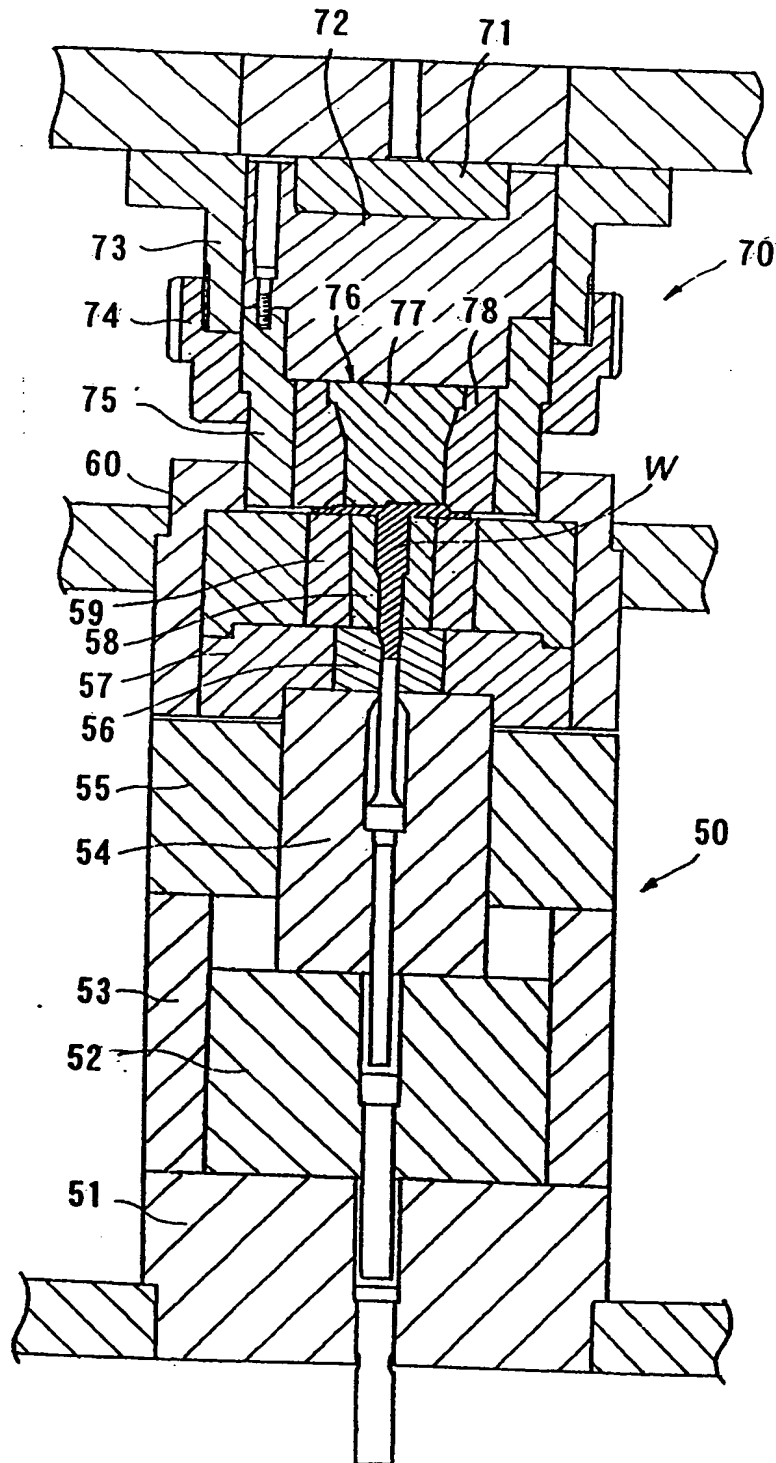


FIG. 44

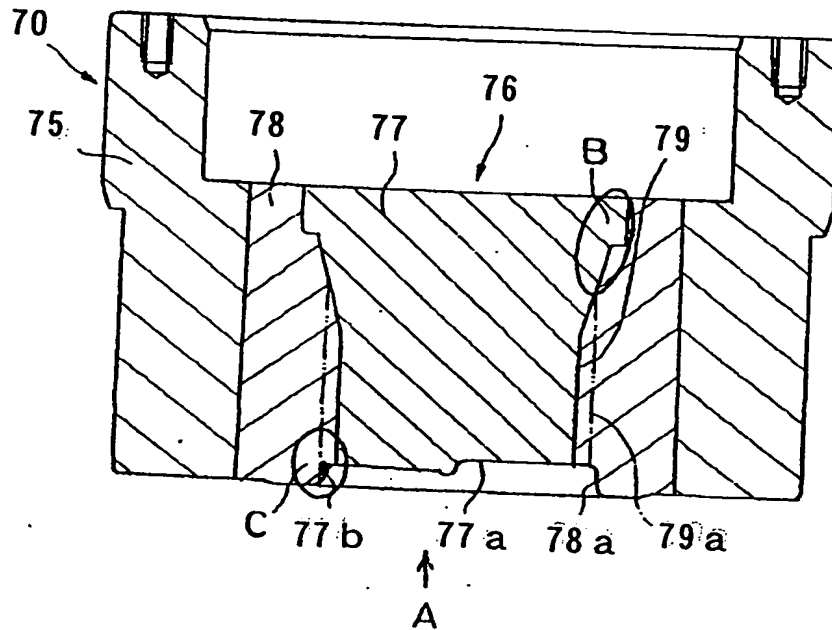


FIG. 45

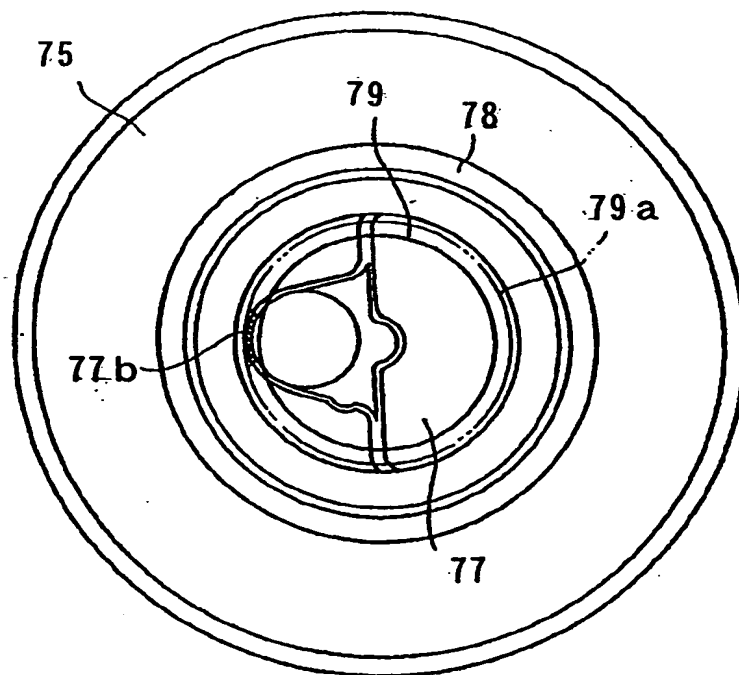


FIG. 46

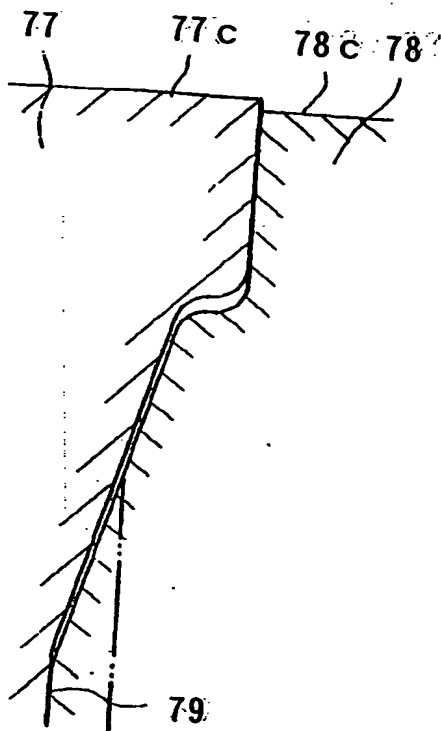


FIG. 47

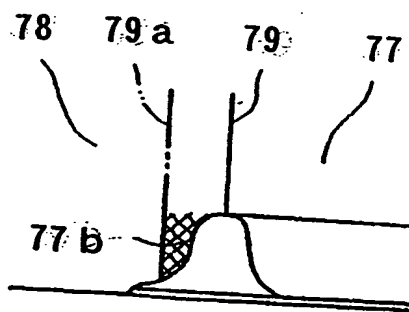


FIG. 48

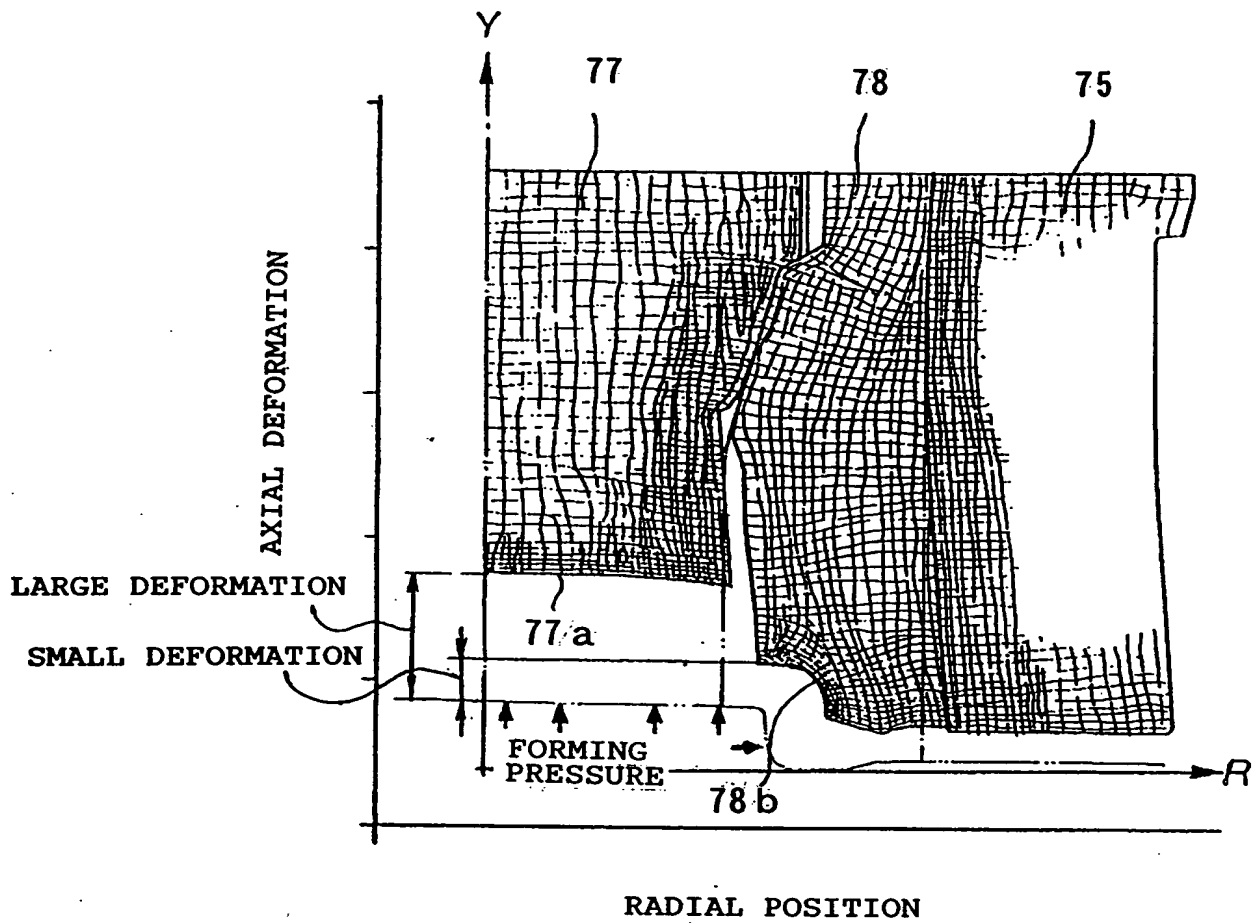


FIG. 49

	Billet manufacturing process					Aspect ratio of carbide (%)	Crack percentage % N=100
	Spherodizing annealing prio to drawing	Drawing	Cutting	Spherodizing annealing subsequent to drawing	Shot bonderizing		
Material 1	None	None	○	○	○	506	35%
Material 2	None	(20%) ○	○	○	○	347	5%
Material 3	○	(20%) ○	○	○	○	300	0%

$$\text{Aspect ratio (\%)} = b/a \times 100$$

